MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

MEASURING INFORMATION GAIN IN THE OBJECTIVE FORCE
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Many researchers are attempting to quantify or understand the value of information, especially for the Army as it enters its transformation. Ascertaining the value through a holistic approach seems so far to be an unsatisfactory solution. Information can be decomposed into various qualities. Three of these qualities, accuracy, completeness, and timeliness, form the basis for this thesis.

This thesis uses a simulation framework developed by the author to analyze the three components of information listed above. The scenario selected is a typical vignette of an Objective Force company-sized element conducting offensive operations against threat elements. Knowledge of the threat was compromised by the presence of decoy elements, as well as previously damaged or killed systems (BDA).

In this scenario, the fires are initiated from standoff ranges. The initial and running assessments of the threat composition are made based on the information provided by sensors on board the unit's organic unmanned aerial vehicles (UAVs). By adjusting the settings on the sensors, differing levels of the information quality components, accuracy, completeness, and timeliness, are obtained.

Analysis of the simulation results help in understanding how components of information quality affect the overall effectiveness of the force as reflected in an efficiency measure. Additionally, critical thresholds for accuracy, completeness, and timeliness of information are pinpointed to inform Objective Force decision makers.

KEYWORDS: Information Quality, Information Gain, Simulation, Objective Force, Future Combat Systems, Design of Experiments

DETERMINING THE IMPORTANCE OF NATIONALITY ON THE OUTCOME OF BATTLES USING CLASSIFICATION TREES
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Throughout history, people have searched for a means of predicting the outcomes of battles. Data analysis is a way of understanding the factors associated with battle outcomes. There are objective factors, such as force ratio, and subjective factors, such as leadership, that affect battles. Subjective factors are hard to determine and thus are usually avoided in models. Here, nationality is investigated as a surrogate for subjective factors. That is, the author wants to see how nationality is associated with battle outcomes by exploring the best available data set on historical land combat-developed by the Center for Army Analysis. The focus is on four countries for which there is sufficient data: the U.S.A., Germany, Britain, and Israel. It is found that these countries historically use a substantial amount of military power to defeat their enemies. In particular, the U.S.A. often has overwhelming force. Using classification tree models, with a correct classification rate of 79 percent, the results suggest that nationality was the most important factor in battles before World War I and the second most important factor during the World Wars. Force ratio was

the most important factor in WWI and artillery ratio in WWII. In the years following WWII, the dominant variable has been air force ratio.

KEYWORDS: Battle Outcomes, Force Ratios, Leadership, Nationality, Historical Combat, Air Force Ratio, WWI, WWII

DETERMINING THE NUMBER OF OFFICERS TO GRADUATE FROM THE NAVAL SCHOOL AND THE NUMBER OF NAVAL SCHOOL GRADUATED OFFICERS TO PROMOTE BY RANK IN ORDER TO MEET ACTUAL AND FUTURE NEEDS OF THE MEXICAN NAVY

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The Mexican Navy is challenged with too few O-1 to O-3 officers and too many O-6 to O-9 officers. This research developed three models to explain the challenge. Through the use of a transition probabilities matrix, Model One predicts the number of graduates from the Mexican Naval School based on accessions. Model Two is a transition probability matrix that uses Model One's output to forecast the distribution of Naval School Graduate Officers (NSGO) by grade over the next ten years.

Model Three is a non-linear objective function that observes gaps between expected inventory and demand of NSGO over the same period. For minimizing these gaps, this model considers three alternatives. The first alternative changes some transition probabilities of the second matrix, while maintaining constant the probabilities of leaving ("out" probabilities) the MN and the probability of graduating from the Naval School (NS). The second alternative also changes some "out" probabilities and maintains constant the last probability. The last alternative also changes the probability of graduating from the NS.

This research provides a method to determine the number of graduates from the NS and the numbers of promotions by grade to meet expected demands for NSGO personnel in the future.

KEYWORDS: Probabilities Transition Matrix, Markov Models, Manpower Supply, Community Management, Attrition

A FRAMEWORK FOR ARMY RESERVE RECRUITING ANALYSIS: ENLISTMENT TO INITIAL TRAINING

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Analysis of U.S. Army Reserve recruiting is conducted across the U.S. Army with data from the Recruit Quota System (REQUEST). A combination of partial manual data entry and a decided lack of tools for large scale data extraction make REQUEST difficult to use for analysis without an extensive knowledge of the system. In this thesis, a process for screening, preparing, and evaluating REQUEST data for subsequent analysis is developed. This process uses data mining software to progressively work through a series of rules that outline data inconsistencies, mark these records for exclusion and later investigation, and generate a "clean" dataset for analysis.

Enlistments over a four year period are examined with respect to Military Occupational Specialty and training program structure. Data from the Army Training Requirements and Resource System (ATRRS) are used to provide an overview of Initial Entry Training seat quotas and usage, and to confirm and/or update training dates in the REQUEST dataset. The joint examination of enlistments and training seats provides new insights into enlistment patterns.

Additional analysis is possible using demographic data provided by the U.S. Army Recruiting Command. Summaries of a few key demographic variables for various subsets of the enlistees are

provided and how similar analyses might prove useful for targeting recruiting efforts and incentives more effectively is discussed.

Good decisions require good data. This thesis is a start in providing a framework for generating quality USAR accession data for analysis.

KEYWORDS: USAR, Recruiting, Demographics, Data Mining, Data Preparation

ENHANCING PERSISTENCE WHEN OPTIMALLY SCHEDULING DEPOT LEVEL REPAIR ACTIVITY FOR THE UNITED STATES MARINE CORPS

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The United States Marine Corps' ability to wage war and its warfighting effectiveness rely heavily on the availability of its tactical ground equipment. The Marine Corps optimizes the warfighting availability of its tactical ground equipment in its depot-level repair plan, which commits $450 million over a six-year horizon. Currently, small changes (for example, budget) to the input to this model produce non-intuitive revisions that are needlessly disruptive. The Marine Corps Materiel Command (MATCOM) recognizes this problem and has asked for enhancement of their current model to include persistent features. It is shown that turbulence can be reduced at little cost in warfighting availability. An approximate, but very fast heuristic in lieu of mathematical optimization to solve this problem is investigated. A simple greedy myopic heuristic quickly produces nearly-optimal advice to the depot-level planning problem.

KEYWORDS: Optimization, Persistence, Heuristic, Maintenance Planning, Depot Repair, Hamming Distance

DETERMINATION OF THE TIMELINE FOR U.S. ARMY AVIATION SYSTEMS TO REACH OPERATIONAL OBSOLESCENCE FOLLOWING TERMINATION OF MODERNIZATION FUNDING

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In this thesis, the definition of the term "Operational Obsolescence" is presented. Models are then produced based on hazard functions of continuous distributions for the eight sub-types of obsolescence that drive overall operational obsolescence of any weapon system. In particular, the sub-type models derive from the two-parameter Weibull, Lognormal and Logistic distributions. A model is then formulated for operational obsolescence based on competing failure rate theory, treating operational obsolescence as a serial system in which overall obsolescence is caused by the occurrence of one of the sub-types of obsolescence. Graphs and analytical techniques are presented to obtain quantitative relationships between modernization timelines and operational obsolescence. Operational obsolescence has not previously been defined, quantified, or studied. Accordingly, there is no data to put into the models. Plausible representative distributions and parameters for each of the models are presented, based on examples from historical weapon systems. The development of a data structure to enable users to utilize the models to solve weapon system obsolescence problems is described. The value of this thesis is to show the relationships between modernization of weapon systems and obsolescence, and provide U.S. Army Acquisition and Support personnel a means to solve the problems associated with operational obsolescence of their systems.

KEYWORDS: Obsolescence, Hazard Function, Weibull, Lognormal, Logistic, Distributions, Weapon System, Reliability, Competing Failure Rate

MULTIVARIATE ANALYSIS OF THE EFFECT OF GRADUATE EDUCATION ON PROMOTION TO ARMY LIEUTENANT COLONEL

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The objective of this thesis is to estimate and explain the effects of graduate education and other factors on promotion to the rank of Lieutenant Colonel (O-5) in the U.S. Army. The focus was primarily on determining whether graduate education provides officers with higher promotion probabilities. Besides graduate education, data that were analyzed include basic demographic traits, the officers' prior enlisted status, and their commissioning source information. The data used in this study were taken from the Active Duty Military Master File for fiscal years 1981 through 2001.

This study develops multivariate logit regression and classification tree models to examine and explore the structure of the data sets. Both the regression models and the classification trees yielded positive results for the effect of graduate education on promotion. According to the regression model results, the odds ratio associated with graduate education is between 1.79 and 2.25. Military Academy and ROTC/Scholarship graduates have higher promotion probabilities than those from other sources, and married officers have higher rates than single officers. Additionally, age has a negative effect on promotion; that is, promotion probability decreases with age. Prior enlisted status, number of dependents, gender, race, and DoD primary occupation code do not seem to have statistically significant effects on promotion.

KEYWORDS: Graduate Education, Promotion, Logistic Regression, and Classification Tree

AN IMPROVED UNSUPERVISED MODELING METHODOLOGY FOR DETECTING FRAUD IN VENDOR PAYMENT TRANSACTIONS

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In this thesis, a standardized procedure for detecting fraud in Defense Finance and Accounting Service (DFAS) vendor payment transactions through Unsupervised Modeling (cluster analysis) is proposed. Clementine Data Mining software is used to construct unsupervised models of vendor payment data using the K-Means, Two Step, and Kohonen algorithms. Cluster validation techniques are applied to select the most useful model of each type, which are then combined to select candidate records for physical examination by a DFAS auditor. This unsupervised modeling technique utilizes all the available valid transaction data, much of which is not admitted under the current supervised modeling procedure. The author's procedure standardizes and provides rigor to the existing unsupervised modeling methodology at DFAS. Additionally, a new clustering approach called Tree Clustering, which uses Classification and Regression Trees to cluster data with automatic variable selection and scaling, is demonstrated. A Recommended SOP for Unsupervised Modeling, detailed explanation of all Clementine procedures, and implementation of the Tree Clustering algorithm are included as appendices.

KEYWORDS: Cluster Analysis, Cluster Validation, Data Mining, Fraud Detection, K-Means, Kohonen, Tree Clustering, Two Step, Unsupervised Modeling

AN ANALYSIS OF THE PREDICTION ACCURACY OF THE U.S. NAVY REPAIR TURN-AROUND TIME FORECAST MODEL

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In this thesis, the forecast accuracy of repair times for a subset of repairable U.S Navy inventory items is examined. Forecasts are currently calculated using the Uniform Inventory Control Program (UICP) on a quarterly basis. The UICP model uses the time of repairs completed in the current quarter to update a "file" value in order to forecast the repair times for the following quarter. Forecasts are calculated separately for repairable items grouped into families. This thesis demonstrates that aggregation repairs by their completion dates, as currently done by the UICP model, causes forecast to be affected by the nature of the repair arrival process. The more that this process differs from a Poisson process, the more that the forecast values are affected. Using bootstrap simulations, the effect of the repair process on the forecasting is quantified. This thesis also explores alternatives to the UICP model for forecasting repair times. In particular, an approach that utilizes repairs that have not been completed by the end of the current quarter is developed.

KEYWORDS: Forecasting, Statistics, Repairable, Inventory

OPTIMIZING THE ALLOCATION OF SENSOR ASSETS FOR THE UNIT OF ACTION

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The U.S. Army's Objective Force is being developed as a faster, lighter, more rapidly deployable alternative to the current force structure. The development of a strategy for the allocation of the Unit of Action's organic sensing assets is necessary to achieve the maximum situational awareness and information dominance required for successful combat operations on the future battlefield.

This thesis presents a methodology for finding an appropriate mix and allocation strategy for organic Unit of Action sensors in a given scenario. Three aggregate levels are identified: sensors, platforms, and packages, and performance measures are developed at each level.

Two optimization models were developed: (1) a Sensor Allocation Model that, given a fixed mix or inventory, allocates assets to target areas on the battlefield, and (2) a Sensor Mix Model that suggests an organic mix of sensors for consideration in developing the Objective Force structure. These models have the additional potential for use as an operational decision support tool for unit commanders.

The notional data set used for model development included ten platform types, ten target clusters, ten target categories, four enemy orders of battle, and four outcomes, however, these inputs are easily modified based on the requirements of the user or analyst.

KEYWORDS: Optimization, Objective Force, Unit of Action, Unmanned Aerial Vehicles, Sensors, Sensor Allocation, Mixed Integer Program, MIP, Operations Research

MASTER OF SCIENCE
IN
PHYSICAL OCEANOGRAPHY

RIP CURRENT SPACING IN RELATION TO WAVE ENERGETICS AND DIRECTIONAL SPREADING

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Rip current spacings are compared with wave energetics and directional spreading in the Southern Monterey Bay. Southern Monterey Bay affords a unique environment to study rip currents, owing to their prevalence created by near-normally incident waves on a sandy shoreline. It is hypothesized that rip current spacing is a function of wave directional spreading and energy flux, based on the morphodynamic modeling by Reniers et al. 2003. A gradient of wave energy flux exists due to headlands and refraction over Monterey Canyon. Rip currents are shown to occur between cusps in the shoreline, allowing cusp spacing to be a surrogate for rip spacing. Rip current spacing was inferred from beach morphology surveys, LIDAR imagery, and Argus cameras, and found to be O(150m) at Sand City and O(300m) at Marina, separated by $\Box 6km$. Measured waves during a two month period using wave-rider buoys, show a gradient of across-shore energy flux between Sand City, $\overline{F}_x \cong 28000(J/m^2)$, and Marina, $\overline{F}_x \cong 33000(J/m^2)$. The two sites have the same peak directional spreading of energy value, $s_{peak} = 14^\circ$, and slightly different bulk values for Sand City, $s_{bulk} = 18^\circ$, and Marina, $s_{bulk} = 20^\circ$. Therefore, the variations in rip current spacing could not be attributed to directional spreading, but appear related to variations in energy flux.

KEYWORDS: Oceanography, Nearshore, Rip Currents, Directional Spreading, Beach Cusps, Coastal Video Imaging

THE FALL TRANSITION OFF CENTRAL CALIFORNIA IN 2002

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During the fall of 2002, the physical oceanographic conditions off Central California were monitored by means of CTD casts and VMADCP current measurements during two cruises. The first cruise, between Pioneer and Hoke Seamounts, included 38 stations and one time series station. The second cruise was sponsored by the Naval Oceanographic Office (NavO) and occupied nine sections along the coast from Pt. Reyes to just south of San Simeon. A total of 86 stations and two time series stations were occupied during the second cruise.

The isosteres, current vectors, and salinity distribution from the cruises provided a clear picture of the circulation pattern during the fall of 2002. A strong shoreward, anticyclonic meander of the California Current was observed along the offshore edge of the survey area. The meander advected Subarctic surface and intermediate waters into the region. Although the meander itself did not cross the dynamic trough that separated inshore and offshore currents, at the point where the meander was adjacent to the trough, a ridge formed which served to transport Subarctic waters into the coastal zone. These fresh waters then were

advected to the north and south along the coast, depending upon the direction of nearshore currents. The observed mesoscale circulation showed the manner in which waters which are upwelled at the coast in summer are replaced by oceanic waters in the fall and winter.

Analysis of the geography of the deep sound channel (DSC) during this period showed that the mean pressure of the DSC was at 586 dbar while the mean sound speed minimum was 1480 m/s. The minimum sound speed varied 3 m/s while the pressure of the minimum varied by 330 dbars. The shape of the pycnocline controlled the pressure and depth of the DSC in the region.

KEYWORDS: California Current System, Fall Transition, Deep Sound Channel

WAVE PROPAGATION OVER COMPLEX BATHYMETRY

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Swell propagates across thousands of kilometers of ocean in almost unchanged parallel wave fronts. Within the nearshore region however, refraction causes wave fronts to turn toward shallow depths, transforming the wave field. The Nearshore Canyon Experiment (NCEX) Pilot, conducted from October 10 to October 17, 2002, observed wave transformation across the Scripps and La Jolla canyon system near San Diego, California. Four Datawell Directional Waverider Buoys, three Nortek Vector PUV recorders, and two pressure sensors were deployed in depths ranging from 10 to 300 m. Observed energy density spectra and mean propagation directions were examined for three case studies representative of the range of observed swell conditions. Observations were compared to predictions of a back-refraction model provided by Dr. William O'Reilly. Observations indicate that refraction causes the waves to propagate along the deep axes of the Scripps and La Jolla canyons. At the shallow canyon heads, the convergence and divergence of ray trajectories cause extreme (2-3 orders of magnitude!) spatial variations in wave energy. Considering the complexity of the canyon environment, predictions of wave transformation agree surprisingly well with observations.

KEYWORDS: Refraction, Swell Transformation, Scripps Canyon

EFFECTS OF THERMOBARICITY ON COUPLED ICE-MIXED LAYER THERMODYNAMICS

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The unique properties of the temperature and salinity profiles for polar oceans are critical for high-latitude mixed layer thermodynamics. In the Polar regions, the water column is coldest and freshest at the surface where ice may be present. This density structure often leads to entrainment and affects both the mixed layer depth and the ice thickness.

Thermobaricity, the combined dependence of seawater thermal expansion on temperature and pressure, magnifies the buoyancy flux associated with mixed layer convection. When thermobaricity amplifies entrainment so that the heat into the mixed layer is greater than the heat leaving the water column, the mixed layer warms and any existing ice begins to melt. Similarly, if the heat entrained is less than the heat leaving the column, the mixed layer cools and freezing occurs at the surface. In the former situation a polynya, or region of no ice surrounded by ice coverage, may form.

A one-dimensional vertical model is built, and trial cases are run to show the intricate relationships that govern the heat and salt fluxes and subsequent ice thickness. The model shows the importance of thermobaricity to the air-sea-ice interactions. It also offers significant insight into how relatively constant atmospheric forcing can lead to polynya-like conditions.

KEYWORDS: Mixed Layer, Thermobaricity, Entrainment, Polynya

THE BOTTOM BOUNDARY LAYER UNDER SHOALING INNER SHELF SOLITONS

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The effects of shoaling inner shelf solitons on the bottom boundary layer have been observed and analyzed over a two month summer period at the Monterey Inner Shelf Observatory in Monterey, California, during 2002. Utilizing CTD data to characterize the temperature field of the water column, Acoustic Doppler Current Profiler (ADCP) data to measure the velocity structure from 3m height above the bed (HAB) to the near surface, and Bistatic Doppler Velocity Sediment Profiler (BDVSP) data to measure the velocity structure and sediment concentration from a range of 60cm to 1cm HAB, solitary internal waves and internal tidal bores were regularly observed at the observation site. These events were characterized by their large isotherm displacements and the sudden change from near surface to near bed stratification as the internal tidal bores passed the observation site. Cross-shore timeseries revealed that the strongest events pushed water onshore near the surface and offshore near the bed, indicating a baroclinic water column during their passage. To analyze their effects on the bottom boundary layer, 3m HAB ADCP and BCDV velocities were compared with backscatter data and surface gravity wave energy at 3m HAB to determine their relative contribution to bed stress and resulting sediment suspension. As the strong internal waves passed, a logarithmic layer formed indicating that shear stress above the bed was occurring. This allowed the friction velocity within the log layer to be estimated. Combining this term with the stress contribution due to the wave energy, the total stress on the bed was then estimated. From this it was determined that typically moderate surface gravity wave forcing at the bed suspended sediment, while solitary internal waves and internal tidal bores continued to transport suspended sediment offshore near the bed.

KEYWORDS: Oceanography, Nearshore, Waves, Currents, Tides, Internal Tidal Bores, Solitons, Sediment Suspension, Sediment Transport